

CLAIMS

1. An integrated optical device comprising:

5 a waveguide body configured to permit propagation of an optical signal having multiple spectral components, wherein at least a substantial portion of said waveguide body comprises an optical amplification medium configured to amplify different spectral components of said multi-component optical signal;

10 a spectral combiner/divider near a boundary of said waveguide body, wherein said spectral combiner/divider is configured such that

15 a spatial distribution of an optical signal propagating to and from said spectral combiner/divider is a function of respective component wavelengths of said multi-component optical signal, and

20 a substantial portion of said optical signal propagates through said optical amplification medium; and

25 a primary input/output channel defined in said waveguide body and a set of displaced input/output channels defined in said waveguide body, wherein

20 a displacement of each of said displaced input/output channels from said primary input/output channel is defined at least in part by said spectral combiner/divider, and

25 a substantial portion of said optical signal in at least one of said primary input/output channel and said set of displaced input/output channels propagates through said optical amplification medium.

2. An integrated optical device as claimed in claim 1 wherein a major portion of said waveguide body comprises said optical amplification medium.

3. An integrated optical device as claimed in claim 1 wherein substantially all of said waveguide body comprises said optical amplification medium.



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4. An integrated optical device as claimed in claim 1 wherein said waveguide body and said spectral combiner/divider are configured such that at least a portion of said optical signal propagating to said spectral combiner/divider and at least a portion of said optical signal propagating from said spectral combiner/divider propagate through said optical amplification medium.

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5. An integrated optical device as claimed in claim 4 wherein:

10 said primary input output channel, said spectral combiner/divider, and said set of displaced input/output channels define a folded optical path along which said optical signal propagates; and

10 said optical amplification medium is present along multiple legs of said folded optical path.

15 6. An integrated optical device as claimed in claim 1 wherein said spectral combiner/divider is configured such that substantially all of said optical signal propagating to and from said spectral combiner/divider in said waveguide body propagates through said optical amplification medium.

20 7. An integrated optical device as claimed in claim 1 wherein a substantial portion of said optical signal in said primary input/output channel and said set of displaced input/output channels propagates through said optical amplification medium.

25 8. An integrated optical device as claimed in claim 1 wherein said waveguide body comprises a doped waveguide.

9. An integrated optical device as claimed in claim 1 wherein said waveguide body comprises a doped glass slab.

30 10. An integrated optical device as claimed in claim 1 wherein said optical amplification medium comprises a doped waveguide material.

11. An integrated optical device as claimed in claim 10 wherein said waveguide material is selected from a glass, a polymer, and combinations thereof.

12. An integrated optical device as claimed in claim 11 wherein said glass comprises silica.

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13. An integrated optical device as claimed in claim 10 wherein said doped waveguide material comprises a dopant selected from the rare earth elements and transition metals.

14. An integrated optical device as claimed in claim 1 wherein said spectral combiner/divider is secured to said boundary of said waveguide body.

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15. An integrated optical device as claimed in claim 1 wherein said spectral combiner/divider is formed at an interface with said boundary of said waveguide body.

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16. An integrated optical device as claimed in claim 1 wherein said spectral combiner/divider is formed in said waveguide body.

17. An integrated optical device as claimed in claim 1 wherein said spectral combiner/divider is optically coupled to said boundary of said waveguide body.

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18. An integrated optical device as claimed in claim 1 wherein said spectral combiner/divider is formed integral with said waveguide body as an extension of said waveguide body.

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19. An integrated optical device as claimed in claim 1 wherein said spectral combiner/divider comprises a reflective grating structure.

20. An integrated optical device as claimed in claim 19 wherein said grating structure is secured to said waveguide body at a curved interface with said waveguide body.

21. An integrated optical device as claimed in claim 1 wherein said spectral combiner/divider comprises at least one component selected from: a reflective grating structure, an echelle grating, a holographically-formed reflective grating, a Rowland circle grating, a reflector stack, a wavelength selective interference filter, a flat specular reflection surface, a side-tap waveguide grating, a Bragg grating, and a super-dispersive prism, a volume phase grating, and combinations thereof.

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22. An integrated optical device as claimed in claim 1 wherein said primary input/output channel and said set of displaced input/output channels are defined in said waveguide body by input/output structure formed within said waveguide body.

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23. An integrated optical device as claimed in claim 1 wherein said primary input/output channel and said set of displaced input/output channels are defined in said waveguide body by input/output structure formed at an interface with said waveguide body.

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24. An integrated optical device as claimed in claim 1 wherein said primary input/output channel and said set of displaced input/output channels are defined in said waveguide body by input/output structure optically coupled to the waveguide body.

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25. An integrated optical device as claimed in claim 1 wherein said displacement of each of said displaced input/output channels includes distance and direction components.

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26. An integrated optical device as claimed in claim 1 wherein said primary input output channel, said spectral combiner/divider, and said set of displaced input/output channels define a folded optical path along which said optical signal propagates.

27. An integrated optical device as claimed in claim 26 wherein said integrated optical device further comprises a partially transmissive reflector positioned along said optical path.

28. An integrated optical device as claimed in claim 27 wherein said spectral combiner/divider defines a first fold in said optical path and said partially transmissive reflector defines a second fold in said optical path.

5 29. An integrated optical device as claimed in claim 28 wherein said integrated optical device further comprises an additional reflector defining a third fold in said optical path.

10 30. An integrated optical device as claimed in claim 29 wherein said first, second, and third folds in said optical paths are such that said primary input/output channel and said set of displaced input/output channels are defined on a common face of said waveguide body.

31. An integrated optical device as claimed in claim 29 wherein said spectral combiner/divider and said additional reflector are formed at a curved periphery of said waveguide body.

15 32. An integrated optical device as claimed in claim 27 wherein said partially transmissive reflector is formed in said waveguide body.

33. An integrated optical device as claimed in claim 26 wherein said integrated optical device further comprises an optical signal monitor positioned along said optical path.

20 34. An integrated optical device as claimed in claim 33 wherein said optical signal monitor comprises a partially transmissive reflector and a detector positioned to receive a portion of said optical signal partially transmitted through said reflector.

25 35. An integrated optical device as claimed in claim 26 wherein said integrated optical device further comprises an optical signal filter positioned along said optical path.

36. An integrated optical device as claimed in claim 35 wherein said optical signal filter comprises a wavelength selective reflector.

37. An integrated optical device as claimed in claim 1 wherein said primary input/output channel defines a multidirectional path propagating through said optical amplification medium.

5 38. An integrated optical device as claimed in claim 37 wherein said multidirectional path comprises a spiral component.

39. An integrated optical device as claimed in claim 37 wherein said multidirectional path comprises a **folded spiral component**.

10 40. An integrated optical device as claimed in claim 1 wherein said primary input/output channel defines a configuration designed to yield optical signal amplification sufficient to offset optical losses in said integrated optical device.

15 41. An integrated optical device as claimed in claim 40 wherein a magnitude of said offset is sufficient to balance said signal amplification and said optical losses.

42. An integrated optical device as claimed in claim 40 wherein said configuration of said input/output channel relates to a position of said input/output channel relative to a high pump density region of said integrated optical device.

20 43. An integrated optical device as claimed in claim 42 wherein:
said integrated optical device further comprises a pump source; and
said high pump density region is defined by said pump source.

25 44. An integrated optical device as claimed in claim 1 wherein said integrated optical device is configured to enable balance of optical signal amplification and optical losses attributable to said integrated optical device.

30 45. An integrated optical device as claimed in claim 44 wherein said balance of said optical signal amplification and said optical losses is a function of one or more of:

an optical configuration of said primary input/output channel;
a doping level of said optical amplification medium; and
an optical length of said optical signal propagating to and from said spectral combiner/divider.

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46. An integrated optical device as claimed in claim 45 wherein said optical configuration of said primary input/output channel comprises an optical path length of said primary input/output channel.

10 47. An integrated optical device as claimed in claim 44 wherein said balance of said optical signal amplification and said optical losses is a function of:

an optical configuration of said primary input/output channel;
a doping level of said optical amplification medium; and
an optical length of said optical signal propagating to and from said spectral combiner/divider.

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48. An integrated optical device comprising:

20 a waveguide body configured to permit propagation of an optical signal having multiple spectral components, wherein at least a substantial portion of said waveguide body comprises an optical amplification medium configured to amplify different spectral components of said multi-component optical signal;

25 a spectral combiner/divider configured such that a spatial distribution of an optical signal propagating to and from said spectral combiner/divider is a function of respective component wavelengths of said multi-component optical signal and a substantial portion of said optical signal propagates through said optical amplification medium; and

30 a primary input/output channel defined in said waveguide body and a set of displaced input/output channels defined in said waveguide body, wherein said primary input/output channel defines a multidirectional path propagating through said optical amplification medium.

49. An integrated optical device comprising:

5 a waveguide body configured to permit propagation of an optical signal having multiple spectral components, wherein at least a substantial portion of said waveguide body comprises an optical amplification medium configured to amplify different spectral components of said multi-component optical signal;

10 a spectral combiner/divider configured such that a spatial distribution of an optical signal propagating to and from said spectral combiner/divider is a function of respective component wavelengths of said multi-component optical signal and a substantial portion of said optical signal propagates through said optical amplification medium; and

15 a primary input/output channel defined in said waveguide body and a set of displaced input/output channels defined in said waveguide body, wherein said primary input/output channel defines a configuration designed to yield optical signal amplification sufficient to offset optical losses in said integrated optical device.

20 50. An integrated optical device as claimed in claim 49 wherein said integrated optical device is configured to enable balance of optical signal amplification and optical losses attributable to said integrated optical device.

25 51. An integrated optical device comprising:

an erbium or ytterbium-doped glass slab waveguide body configured to permit propagation of an optical signal having multiple spectral components, wherein said waveguide body is doped sufficiently for amplification of different spectral components of said multi-component optical signal; and

30 a spectral combiner/divider at a curved periphery of said waveguide body, wherein said curved periphery and said spectral combiner/divider are configured such that

said multi-component optical signal propagates from an input/output face of said waveguide body, through said waveguide body to said spectral combiner/divider at said curved periphery of said waveguide body, back through

5 said waveguide body, as reflected by said spectral combiner/divider, and to said input/output face of said waveguide body,

10 a spatially condensed optical signal propagating from an input/output face of said waveguide body to said spectral combiner/divider, and from said spectral combiner/divider to said input/output face, is spatially expanded by said spectral combiner/divider according to respective component wavelengths of said multi-component optical signal, and

15 a spatially expanded optical signal propagating from an input/output face of said waveguide body to said spectral combiner/divider, and from said spectral combiner/divider to said input/output face, is spatially condensed by said spectral combiner/divider according to respective component wavelengths of said multi-component optical signal, wherein

20 a 15 said spatially condensed optical signal propagating between said input/output face of said waveguide body and said spectral combiner/divider defines a primary input/output channel in said waveguide body,

25 a 20 said spatially expanded optical signal propagating between said input/output face of said waveguide body and said spectral combiner/divider defines a set of displaced input/output channels in said waveguide body, and

30 a displacement of each of said displaced input/output channels from said primary input/output channel along said input/output face is defined by said spectral combiner/divider.

25 52. An integrated optical device as claimed in claim 51 further comprises:

 a primary ridge waveguide optically coupled to said waveguide body along said primary input/output channel; and

 a set of displaced ridge waveguides optically coupled to said waveguide body along said set of displaced input/output channels.

53. An integrated optical device as claimed in claim 52 wherein said primary ridge waveguide and said set of displaced ridge waveguides are parallel to each other.

54. An integrated optical device as claimed in claim 51 further comprises:

5 a primary buried waveguide optically coupled to said waveguide body along said primary input/output channel; and
a set of displaced buried waveguides optically coupled to said waveguide body along said set of displaced input/output channels.

10 55. An integrated optical device as claimed in claim 54 wherein said primary buried waveguide and said set of displaced buried waveguides are parallel to each other.

56. An optical network comprising:

15 at least one transmitter configured to transmit an optical signal having multiple spectral components;
at least one regenerator configured to amplify said multi-component optical signal; and
at least one receiver configured to receive said multi-component optical signal, wherein
at least one of said transmitter, regenerator, and receiver comprise at least one integrated optical
20 device comprising:

a waveguide body configured to permit propagation of an optical signal
having multiple spectral components, wherein at least a substantial portion of said
waveguide body comprises an optical amplification medium configured to
amplify different spectral components of said multi-component optical signal;

25 a spectral combiner/divider near a boundary of said waveguide body,
wherein said spectral combiner/divider is configured such that
a spatial distribution of an optical signal propagating to and
from said spectral combiner/divider is a function of respective
component wavelengths of said multi-component optical signal,
and

a substantial portion of said optical signal propagates through said optical amplification medium; and a primary input/output channel defined in said waveguide body and a set of displaced input/output channels defined in said waveguide body, wherein

5 a displacement of each of said displaced input/output channels from said primary input/output channel is defined at least in part by said spectral combiner/divider, and

a substantial portion of said optical signal in at least one of said primary input/output channel and said set of displaced input/output channels propagates through said optical amplification medium.

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15 57. An optical network as claimed in claim 56 wherein said transmitter comprises said integrated optical device and said primary input/output channel is coupled to an input channel of said regenerator.

58. An optical network as claimed in claim 56 wherein said receiver comprises said integrated optical device and said primary input/output channel is coupled to an output channel of said regenerator.

20 59. An optical network as claimed in claim 56 wherein said regenerator comprises said integrated optical device and said primary input/output channel is coupled to an output channel of said transmitter.

25 60. An optical network as claimed in claim 56 wherein said optical network comprises a plurality of said integrated optical devices.

30 61. An optical network as claimed in claim 60 wherein said transmitter comprises one of said plurality of integrated optical devices and said receiver comprises another of said plurality of integrated optical devices.

62. An optical network as claimed in claim 60 wherein said transmitter comprises one of said plurality of integrated optical devices, said receiver comprises another of said plurality of integrated optical devices, and said regenerator comprises yet another of said plurality of 5 integrated optical devices.

63. A telecommunications network comprising:

10 at least one telecommunications transmitter configured to transmit an optical telecommunications signal having multiple spectral components;
at least one regenerator configured to amplify said multi-component optical signal; and
at least one telecommunications receiver configured to receive said multi-component optical signal, wherein at least one of said transmitter, regenerator, and receiver comprise an integrated optical device comprising:

15 a waveguide body configured to permit propagation of an optical signal having multiple spectral components, wherein at least a substantial portion of said waveguide body comprises an optical amplification medium configured to amplify different spectral components of said multi-component optical signal;
a spectral combiner/divider near a boundary of said waveguide body, wherein said spectral combiner/divider is configured such that

20 a spatial distribution of an optical signal propagating to and from said spectral combiner/divider is a function of respective component wavelengths of said multi-component optical signal, and

25 a substantial portion of said optical signal propagates through said optical amplification medium; and
a primary input/output channel defined in said waveguide body and a set of displaced input/output channels defined in said waveguide body, wherein

a displacement of each of said displaced input/output channels from said primary input/output channel is defined at least in part by said spectral combiner/divider, and

5 a substantial portion of said optical signal in at least one of said primary input/output channel and said set of displaced input/output channels propagates through said optical amplification medium.

10 64. An integrated optical device as claimed in claim 1 wherein a surface of said waveguide body is configured as a sensing region and said waveguide body is configured such that matter present in said sensing region results in attenuation of an optical signal propagating in said waveguide body.

15 65. An integrated optical device as claimed in claim 1 wherein said waveguide body is configured such that a plurality of waveguide channels corresponding to said displaced input/output channels pass through said sensing region.

20 66. An integrated optical device as claimed in claim 1 wherein said waveguide body is configured such that a primary waveguide channel corresponding to said primary input/output channel passes through said sensing region.